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Electrically conductive sintered ceramics and ceramic heaters

Abstract:

An electrically conductive sintered ceramics of the present invention comprises, as the main ingredients thereof, (a) silicon carbide, (b) an inorganic compound which exhibits a positive resistance-temperature coefficient, and preferably (c) a sintering assistant. The electrically conductive sintered ceramics obtained exhibits a positive resistance-temperature coefficient as a whole. A ceramic heater of the invention makes use of the electrically conductive sintered ceramics in an electrically conductive portion thereof. A sintered product which exhibits a positive resistance-temperature coefficient helps to prevent the occurrence of thermal runaway or thermal destruction.

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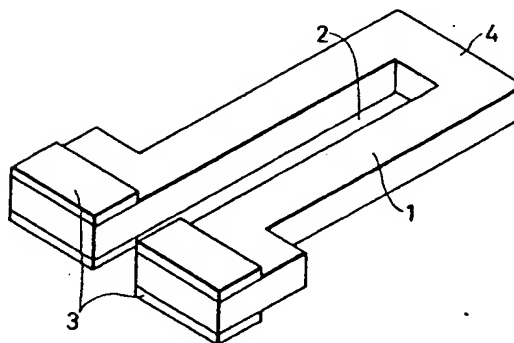
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(54) Electrically conductive sintered ceramics and ceramic heaters.

(57) An electrically conductive sintered ceramics of the present invention comprises, as the main ingredients thereof, (a) silicon carbide, (b) an inorganic compound which exhibits a positive resistance-temperature coefficient, and preferably (c) a sintering assistant. The electrically conductive sintered ceramics obtained exhibits a positive resistance-temperature coefficient as a whole.

A ceramic heater (1) of the invention makes use of the electrically conductive sintered ceramics in an electrically conductive portion thereof.

A sintered product which exhibits a positive resistance-temperature coefficient helps to prevent the occurrence of thermal runaway or thermal destruction.



TITLE OF THE INVENTION

ELECTRICALLY CONDUCTIVE SINTERED CERAMICS
AND CERAMIC HEATERS

BACKGROUND OF THE INVENTION5 FIELD OF THE INVENTION

The present invention relates to electrically
conductive sintered ceramics and to ceramic
heaters using these ceramics

DESCRIPTION OF THE PRIOR ART

10 Silicon carbide has an excellent hardness, strength
and resistance against oxidation and corrosion. It
is also known that silicon carbide has a large resistance
against impact under high-temperature conditions,
owing to its small coefficient of thermal expansion
15 and high heat conductivity. Silicon carbide with these
excellent characteristics is a promising material for
a wide field of industrial applications such as engine
parts for automobiles, turbine members, heat exchanger
members, crucibles for melting metals, and jigs for
20 use at high temperatures. In order to expand the
applications of silicon carbide, attempts have been
made to blend silicon carbide with ceramics or
intermetallic compounds to improve some characteristic
of a sintered product of silicon carbide, or to impart
25 new functions thereto. Examples of such studies are
disclosed in the specifications of U.S. Patent Nos.

3,875,476 and 3,895,219. The sintered products obtained by this prior art, however, have negative resistance-temperature coefficients and present the probability of being destroyed by heat.

5 Conventional glow plugs can be divided into those of the metal-sheathed type (indirect heating type) and the uncovered coil type (direct heating type). A glow plug of the sheathed type is constructed by pouring a powder of a ceramic having a resistance
10 against heat and heat conductivity, such as magnesium oxide powder, into and around the heat-producing coil in a metal tube. With a glow plug of the uncovered coil type, on the other hand, the heat-producing coil is exposed in the engine.

15 A glow plug of the former type is rigid and has a great durability against the combustion gases, but is poor in heat transmission, requires a time of longer than 5 seconds before the temperature on the surface of the sheath reaches the starting point, and hence
20 lacks a rapid heating performance. Further, if attempts are made to increase the heating speed, the temperature of the heat-producing coil increases to close to the melting point of the heat-producing element to reduce its durability considerably. There-
25 fore an upper limit of 950°C is imposed on the surface

temperature of the sheath. A glow plug of the latter type, on the other hand, can be heated rapidly, but the heat-producing element is subject to deterioration due to the combustion gases, and short-circuiting can easily develop due to the adhesion of carbon. From the standpoint of corrosion at high temperatures, furthermore, a temperature of 900°C may be the limit on the surface temperature of the heat-producing coil. Therefore, glow plugs of the sheath type are mainly used at the moment, despite their poor performance for rapid heating.

In recent years, however, an increasing demand had risen for diesel-engined automobiles to start as quickly as gasoline-engined automobiles. Under such circumstances, glow plugs of the direct heating type (surface heating type) have been reconsidered, and there is a strong desire to develop a heater element for glow plugs which can be heated quickly, and which has an excellent durability at high temperatures.

SUMMARY OF THE INVENTION

The object of the present invention is to provide an electrically conductive sintered ceramics which has an electric conductivity close to that of a metal, and provide a ceramic heater which is composed of the electrically conductive sintered ceramics

and which is free from being destroyed by heat.

The electrically conductive sintered ceramics of the present invention comprises (a) silicon carbide (SiC), (b) an inorganic compound having a positive resistance-temperature coefficient, and preferably
5 (c) a sintering additive, as the main ingredients thereof, the sintered product exhibiting a positive resistance-temperature coefficient.

When a sintered product or inorganic compound
10 having a positive resistance-temperature coefficient is heated, its electrical resistance increases with temperature. If a sintered product has a negative resistance-temperature coefficient as do conventional products, the electrical resistance decreases with
15 increasing temperature, and the current increases under constant-voltage conditions. Namely, heat is produced spontaneously, the electrical resistance decreases correspondingly, and the current increases further, raising the probability of thermal runaway
20 or thermal destruction. Therefore, if a sintered product exhibits a positive resistance-temperature coefficient, thermal runaway or thermal destruction can be prevented by using the sintered product in the electrically conductive part of a ceramic heater.
25 In order for a sintered product to exhibit a positive

resistance-temperature coefficient, it is essential that component (b) has a positive resistance-temperature coefficient.

Examples of such a component (b) include zirconium
5 boride (ZrB_2) with a resistance-temperature coefficient
of +1.76, titanium boride (TiB_2) with a resistance-
temperature coefficient of +2.78, molybdenum boride
(Mo_2B_5) with a resistance-temperature coefficient of
+3.3, zirconium silicate (ZrSi_2) with a resistance-
10 temperature coefficient of +2.65, molybdenum silicate
(MoSi_2) with a resistance-temperature coefficient of
+6.38, tantalum silicate (TaSi_2) with a resistance-
temperature coefficient of +3.32, titanium nitride
(TiN) with a resistance-temperature coefficient of
15 +2.48, zirconium nitride (ZrN) with a resistance-
temperature coefficient of +4.3, tantalum carbide
(TaC) with a resistance-temperature coefficient of
+1.07, and zirconium carbide (ZrC) with a resistance-
temperature coefficient of +0.95. A sintered product
20 having the desired resistance characteristics can be
obtained even by adding metal powders. This, however,
raises a difficulty concerning resistance to the
oxidation at high temperatures, and the material
obtained is not suitable in a heater for glow plugs.
25 The above examples of component (b) have melting points

of more than 2000°C and resistivities of less than 10^{-4} Ω cm at room temperature.

According to the present invention, the electrically conductive sintered ceramic product should contain
5 between 10 to 200 parts by weight of powder (b) for 100 parts by weight of powder (a). When the amount of component (b) is within this range, (1) the resistivity is less than 1 Ω cm, (2) the resistance-temperature coefficient becomes positive, (3) the sintered product
10 has an increased strength, and (4) an excellent resistance to oxidation is exhibited under high-temperature conditions. The sintering additive (c) should preferably be an aluminum compound or a boron compound, and a quantity of 0.1 to 3 % by weight
15 should be used, based on the aluminum and/or boron content. Under this condition, (1) the relative density of the sintered product becomes as high as 85 % or higher of the theoretical density, and (2) there is no possibility of any increase in resistivity. The
20 particle diameter of powder (a) should preferably be less than 10 μ m.

According to the present invention, a mixture consisting chiefly of component (a), component (b), and preferably component (c) is pre-molded, and is then
25 be sintered by hot-pressing in a non-oxidizing atmosphere

under the conditions of a temperature of between
1700° to 2300°C and a pressure of between 10 to 500
bar. If the mixture is sintered in an oxidizing
atmosphere, the surfaces of the starting powders are
5 oxidized, making it difficult to obtain a dense
sintered product. If the hot-press sintering is effected
at a temperature lower than 1700°C, it becomes difficult
to obtain a dense sintered product having a relative
density of more than 85 %. If the hot-press sintering
10 is effected at a temperature higher than 2300°C, on
the other hand, the mixture is sintered too much,
giving rise to the occurrence of voids which reduce
the strength. When the sintering temperature is within
above range, hot pressing will usually be effected
15 under a pressure of 10 to 500 bar, to obtain a
very dense sintered product.

The thermal conductivity and thermal expansion
coefficient of the silicon carbide type of composite
ceramic material can be controlled by substituting
20 less for than 50 % by weight of component (b) one or
more high melting point compounds having melting
points of higher than 2000°C. If the additional
components have melting points of more than 2000°C,
the silicon carbide composite ceramic material
25 produced will not lose any hardness or strength under

high-temperature conditions. Further, when less than 50 % by weight of component (b) is replaced with an amount of other compounds, the silicon carbide composite ceramic material produced will lose its characteristics. More preferably, less than 30 % of component (b) should be replaced by of additional components.

The ceramic heater of the present invention is characterized in that the electrically conductive sintered ceramics is used for the electrically conductive member thereof, and is suitable for use in a heater of the direct heating type.

When studying heater materials of the direct heating type, the inventors of the present invention have discovered that a rapid heating performance can be achieved if the resistance of the heater is reduced to pass a heavy current instantaneously, that durability under high-temperature conditions can be accomplished if the heater is composed of a material containing compounds having high melting points and resistance to oxidation, and that the heater material should have a positive resistance-temperature coefficient to prevent runaway of current when heat is produced and control the current easily so that the temperature on the surface of the heater is maintained constant because

of the resistance-temperature coefficient. Through extensive studies on heater materials having the above characteristics, the inventors have found that a silicon carbide composite sintered ceramic product has a low resistivity and a positive resistance-temperature coefficient, and exhibits durability in the high operating temperature ranges of a glow plug heater.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view of a heater for a glow plug according to an embodiment of the present invention;

Fig. 2 is a diagram of the temperature-rise characteristics of the heater for a glow plug according to the embodiment of Fig. 1;

Fig. 3 is a diagram showing the changes of resistance during a current-carrying durability test using the heater for a glow plug according to the embodiment of Fig. 1; and

Fig. 4 is a diagram showing the changes of resistance during a high-temperature durability test using the heater for a glow plug according to the embodiment of Fig. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

100 parts by weight of black SiC powder having an average particle diameter of 10 μm was mixed with

2 parts by weight of Al_2O_3 powder (1 % by weight based on the aluminum content) having an average particle diameter of 1 μm , and 80 parts by weight of ZrB_2 powder having an average particle diameter of 2 μm . The powder mixture was introduced into a metal mold and was molded under a pressure of 1000 bar. The molded product was introduced into dies of graphite, and was sintered by the hot-press method at a vacuum pressure of $1.3 \cdot 10^{-3}$ to $1.3 \cdot 10^{-5}$ mbar. The sintering was effected under a pressure of 200 bar, while the temperature was raised from room temperature to $2050^\circ C$ over a period of about 2 hours, was maintained at the temperature of $2050^\circ C$ for one hour, and then the product was permitted to cool by turning off the power supply. The pressure was reduced after the temperature had dropped to less than $1500^\circ C$. The thus obtained composite sintered product ($SiC-ZrB_2$) had a relative density of 98 % (relative to the theoretical density of the composition), a bending strength of about 50 N/mm^2 both at room temperature and at $1300^\circ C$, a thermal expansion coefficient of $42 \times 10^{-7}/^\circ C$ (between room temperature and $1000^\circ C$), a resistivity of $5 \times 10^{-4} \Omega cm$ at room temperature, and a resistance-temperature coefficient of about $+0.3 \%/^\circ C$ (between room temperature and $1000^\circ C$).

A cut-out 2 was formed in the thus obtained ZrB_2 -SiC-type heater material 1 shown in Fig. 1 to obtain a U-shaped glow plug heater, and electrodes 3 were formed at both end portions A, B thereof by attaching a heat-resistant metal such as nickel, so that power-supply wires could be connected thereto. This heater was narrower at the U-shaped end 4, and hence generated the highest temperature at this portion. The heater material exhibited a resistivity of $5 \times 10^{-4} \Omega \text{ cm}$ at room temperature, and a resistance of about 0.1 ohm across the electrodes A and B at room temperature.

Fig. 2 shows the results of heating speed measured by connecting the heater element of Fig. 1 to a d-c power-supply circuit and by changing the voltage applied. The resistivity of the heater was 0.1 ohm, the curve (i) represents the case when the temperature of the heater surface was 1200°C , and the curve (ii) represents the case when the temperature of the heater surface was 900°C . When a voltage of 12 volts, the same as that of a storage battery of a car, was applied, a temperature of 900°C was reached in about 0.7 second and a temperature of 1200°C was reached in about 1 second, this is considerably faster than the heating speed of a conventional metal-sheathed heater (which takes 5

to 10 seconds before a temperature of 900°C is reached). When the heater surface was heated at 1000°C by passing an electric current therethrough, the heater resistance was about 0.3 ohm and hence it exhibited a
5 positive resistance-temperature coefficient, providing a heater which is suitable for use in a glow plug.

Fig. 3 shows the changes of resistance (at room temperature) during a current-carrying durability test by repeated voltage-application cycles, each cycle
10 consisting of applying a d-c voltage of 8 volts to the heater element of the embodiment of the invention for 2 seconds (the surface temperature reached about 1100°C after 2 seconds) and halting the flow of current for 30 seconds (the heater element was forcibly air-
15 cooled during this period). In Fig. 3, the abscissa indicates the number of times the cycles were repeated. The resistance did not deteriorate at all even after a test of a hundred thousand cycles, and it was proved that the heater element possessed an excellent current-
20 carrying durability and durability against intermittent heating to about 1100°C .

Fig. 4 shows the changes of resistance (at room temperature) during a high-temperature durability test in which heater elements of the embodiment of the
25 invention were heat-treated in air at 900° to 1200°C

in an electric furnace. The curve (iii) shows the case when a heater element was heat-treated at 1250°C, a curve (iv) shows the case when a heater element was heat-treated at 1200°C, and a curve (v) shows the case when a heater element was heat-treated at 900°C, 1000°C and 1100°C. After heat-treatment for 2000 hours (which was considerably severer than the conditions encountered in practice in a vehicle), the resistance changed within + 5 % when the heater element was heat-treated at less than 1200°C, and by about + 10 % when if heat-treated at 1200°C, indicating the excellent durability of the heater element.

Thus, the electrically conductive sintered ceramic product according to the embodiment of the invention has a low resistivity and hence a rapid heating performance as stated above. Further, owing to the positive resistance-temperature coefficient thereof, the electrically conductive sintered ceramic product is not melted by a runaway current even if it glows. Furthermore, the high melting point and resistance to oxidation thereof make the electrically conductive sintered ceramic product of the invention suitable for use as a heater member for a glow plug of the direct heating type for which a rapid temperature-raising speed and durability at high temperatures are required.

The heater material according to the present invention has a high density, a low specific gravity and an increased strength (between room temperature and 1300°C). Therefore, the heater element can be
5 constructed in a simple form such as rod, plate or U-shaped member. Using the heater material of the embodiment of the invention, therefore, a glow plug can be realized with a simple construction, a small size and a reduced weight when compared with existing
10 metal sheathed glow plugs.

The present invention can be adapted not only to the heater of a glow plug, but also to a variety of heat-generating members, gas-igniting devices, heat-resistant conductors, electrically conductive spacers, and resis-
15 tors.

According to the present invention as described above, a heater material of the direct heating type is provided which exhibits a rapid heating performance, an excellent durability at high temperatures, and which
20 features a simple construction, small size and reduced weight.

Mixtures consisting chiefly of a powder of black silicon carbide having an average particle diameter of 1 μm and a powder of component (b) having an
25 average particle diameter of 5 μm , were molded under a

pressure of 1000 bar, introduced into dies of graphite, and were sintered by a hot press at a vacuum pressure of $1.3 \cdot 10^{-3}$ to $1.3 \cdot 10^{-5}$ mbar. The sintering was effected under a pressure of 300 bar, the temperature was raised from room temperature to 2050°C over a period of about 2 hours, it was maintained at 2050°C for 1 hour, and then the mixture was permitted to cool by turning off the power supply. The pressure was reduced after the temperature had dropped to below 1000°C. The thus obtained silicon carbide composite sintered products, i.e., the electrically conductive sintered ceramic products according to the present invention, and their characteristics, are tabulated below.

Table

Blend composition (% by weight)	Relative density (%)	Hardness H_D (N/mm^2)	Heat conductivity ($W/m K$)	Coefficient of thermal expansion ($\times 10^{-7}/^{\circ}C$)	Resistivity ($\Omega \cdot cm$)
SiC-60% TiB ₂	91	30 000	87	50	4×10^{-4}
SiC-40% TiB ₂	93	29 000	82	48	6×10^{-3}
SiC-20% TiB ₂	95	27 000	79	45	0.8
SiC-40% TiB ₂ -15% ZrB ₂	94	28 000	80	48	6×10^{-4}
SiC-45% TiB ₂ -20% HfB ₂	92	29 000	81	47	2×10^{-4}
SiC-40% TiB ₂ -10% TiC	95	29 000	78	50	1×10^{-3}
SiC-40% TiB ₂ -10% ZrN	92	27 000	76	49	9×10^{-4}
SiC-45% TiB ₂ -20% TaC	91	26 000	86	47	1×10^{-4}
SiC-45% TiB ₂ -10% NbB ₂	93	25 000	93	48	3×10^{-4}

Table (continued)

Blend composition (% by weight)	Relative density (%)	Hardness H_D (N/mm^2)	Heat conductivity ($W/m K$)	Coefficient of thermal expansion ($\times 10^{-7}/^{\circ}C$)	Resistivity (Ωcm)
SiC-40% TiB ₂ -5% WC	94	25 000	90	46	2×10^{-3}
SiC-40% TiB ₂ -5% MoB ₂	94	25 000	86	46	1×10^{-3}
SiC-40% TiB ₂ -10% Al ₂ O ₃	96	24 000	67	61	7×10^{-4}
SiC-50% TiB ₂ -5% B ₄ C	95	31 000	71	47	2×10^{-3}
SiC-50% TiB ₂ -5% ZrO ₂	97	27 000	69	63	2×10^{-3}
SiC-50% TiB ₂ -5% Si ₃ N ₄	92	25 000	88	46	3×10^{-4}
SiC-65% ZrB ₂	99	26 000	68	47	1×10^{-4}
SiC-40% ZrB ₂	98	25 000	70	45	3×10^{-3}
SiC-20% ZrB ₂	97	24 000	73	43	0.1
SiC-40% ZrB ₂ -20% HfB ₂	98	26 000	72	46	9×10^{-5}

Table (continued)

Blend composition (% by weight)	Relative density (%)	Hardness H_D (N/mm^2)	Heat conductivity ($W/m K$)	Coefficient of thermal expansion ($\times 10^{-7}/^{\circ}C$)	Resistivity (Ωcm)
SiC-40% ZrB ₂ -10% TiC	97	28 000	71	48	2×10^{-4}
SiC-40% ZrB ₂ -15% ZrN	96	25 000	68	46	2×10^{-4}
SiC-40% ZrB ₂ -15% TaB ₂	97	27 000	66	47	1×10^{-4}
SiC-40% ZrB ₂ -10% NbC	97	26 000	72	46	9×10^{-5}
SiC-40% ZrB ₂ -5% WC	96	24 000	70	47	4×10^{-4}
SiC-50% ZrB ₂ -5% MoB ₂	98	23 000	72	46	2×10^{-4}
SiC-45% ZrB ₂ -5% Al ₂ O ₃	98	24 000	65	51	2×10^{-4}
SiC-45% ZrB ₂ -5% B ₄ C	98	25 000	67	44	3×10^{-4}

Table (continued)

Blend composition (% by weight)	Relative density (%)	Hardness H_D (N/mm^2)	Heat conductivity ($W/m K$)	Coefficient of thermal expansion ($\times 10^{-7}/^{\circ}C$)	Resistivity (Ωcm)
SiC-50% ZrB ₂ -10% ZrO ₂	98	24 000	67	52	4×10^{-4}
SiC-50% ZrB ₂ -5% Si ₃ N ₄	94	25 000	71	43	1×10^{-4}
SiC-60% TiN	99	24 000	81	61	8×10^{-4}
SiC-40% TiN	98	23 000	79	57	1×10^{-2}
SiC-20% TiN	98	22 000	77	45	0.4
SiC-30% TiN-20% ZrN	97	21 000	76	51	2×10^{-3}
SiC-30% TiN-20% HfN	95	22 000	79	49	3×10^{-3}
SiC-60% TiN-25% ZrB ₂	98	23 000	70	53	6×10^{-4}
SiC-60% TiN-25% TiC	97	24 000	72	56	7×10^{-4}
SiC-60% TiN-25% TiB ₂	98	24 000	84	54	5×10^{-4}

Table (continued)

Blend composition (% by weight)	Relative density (%)	Hardness H_D (N/mm^2)	Heat conductivity ($W/m K$)	Coefficient of thermal expansion ($\times 10^{-7}/^{\circ}C$)	Resistivity (Ωcm)
SiC-60% TiN-10% TaN	94	23 000	81	52	4×10^{-4}
SiC-50% TiN-10% B ₄ C	98	24 000	72	50	6×10^{-3}
SiC-50% TiN-15% Al ₂ O ₃	98	23 000	68	67	9×10^{-3}
SiC-40% TiN-5% Si ₃ N ₄	94	22 000	88	47	1×10^{-2}
SiC-40% TiN-10% ZrO ₂	98	23 000	73	65	7×10^{-2}
SiC-40% TiN-10% ZrC	97	22 000	71	54	6×10^{-3}
SiC-70% ZrN	96	22 000	72	45	6×10^{-5}
SiC-50% ZrN	95	21 000	70	44	3×10^{-4}
SiC-20% ZrN	95	21 000	70	42	0.3
SiC-30% ZrN-10% HfN	92	23 000	68	40	2×10^{-3}

Table (continued)

Blend composition (% by weight)	Relative density (%)	Hardness H_D (N/mm^2)	Heat conductivity ($W/m K$)	Coefficient of thermal expansion ($\times 10^{-7}/^{\circ}C$)	Resistivity ($\Omega \text{ cm}$)
SiC-40% ZrN-10% ZrB ₂	96	23 000	67	46	2×10^{-4}
SiC-30% ZrN-10% TiC	95	24 000	63	49	4×10^{-3}
SiC-35% ZrN-15% TiB ₂	96	24 000	76	44	2.5×10^{-4}
SiC-35% ZrN-10% TaN	93	21 000	75	43	4×10^{-4}
SiC-35% ZrN-5% B ₄ C	95	22 000	63	40	1×10^{-2}
SiC-30% ZrN-10% Al ₂ O ₃	96	22 000	60	56	0.1
SiC-30% ZrN-5% Si ₃ N ₄	92	21 000	75	40	8×10^{-2}
SiC-30% ZrN-10% ZrO ₂	97	21 000	62	53	6×10^{-2}
SiC-30% ZrN-10% ZrC	95	21 000	73	41	4×10^{-3}

As explained above, electrically conductive
sintered ceramics of the above compositions
have resistivities of smaller than 1 Ω cm.

WHAT IS CLAIMED IS

1. An electrically conductive sintered ceramics,
characterized in that it comprises, as the main ingredients
5 thereof, (a) silicon carbide and (b) an inorganic compound
which exhibits a positive resistance-temperature coefficient,
said electrically conductive sintered ceramics exhibiting
a positive resistance-temperature coefficient as a whole.
2. An electrically conductive sintered ceramics according
10 to claim 1, characterized in that said component (b) is
selected from titanium boride, zirconium boride, titanium
nitride and zirconium nitride.
3. An electrically conductive sintered ceramics according
to claim 1, characterized in that the quantity of the
15 powder of said component (b) used is between 10 to 200
parts by weight for 100 parts by weight of the powder of
said component (a).
4. An electrically conductive sintered ceramics,
characterized in that it comprises, as the main ingredients
20 thereof, (a) silicon carbide, (b) an inorganic compound
which exhibits a positive resistance-temperature coefficient,
and (c) a sintering additive, said electrically conductive
sintered ceramics exhibiting a positive resistance-
temperature coefficient as a whole.
- 25 5. An electrically conductive sintered ceramics
according to claim 4, characterized in that said component

(c) is an inorganic compound selected from aluminium and boron compounds, and the quantity thereof in the starting materials mixture is between 0.1 to 3% by weight based on the aluminium or boron content.

- 5 6. An electrically conductive sintered ceramics according to claim 4, characterized in that the quantity of the powder of said component (b) used is between 10 to 200 parts by weight for 100 parts by weight of the powder of said component (a).
- 10 7. An electrically conductive sintered ceramics which exhibits a positive resistance-temperature coefficient as a whole, characterized in that it is obtained by hot-pressing and sintering a mixture composed, as the main ingredients thereof, of (a) silicon carbide,
- 15 and (b) a ceramic material of the non-oxide-type other than silicon carbide, in a non-oxidizing atmosphere, at a temperature of between 1700° to 2300°C, under a pressure of between 10 to 500 bar.
- 20 8. A ceramic heater wherein an electrically conductive portion thereof is composed of an electrically conductive sintered ceramics, characterized in that it comprises, as the main ingredients thereof, (a) silicon carbide and (b) an inorganic compound which exhibits a positive resistance-temperature coefficient,
- 25 said electrically conductive sintered ceramics exhibiting a positive resistance-temperature coefficient as a whole.

9. A ceramic heater according to claim 8,
characterized in that said electrically conductive
sintered ceramics contains a sintering additive.

10. A ceramic heater according to claim 8 or 9,
5 characterized in that the quantity of the powder of
said component (b) used is between 10 to 200 parts
by weight for 100 parts by weight of the powder of
said component (a).

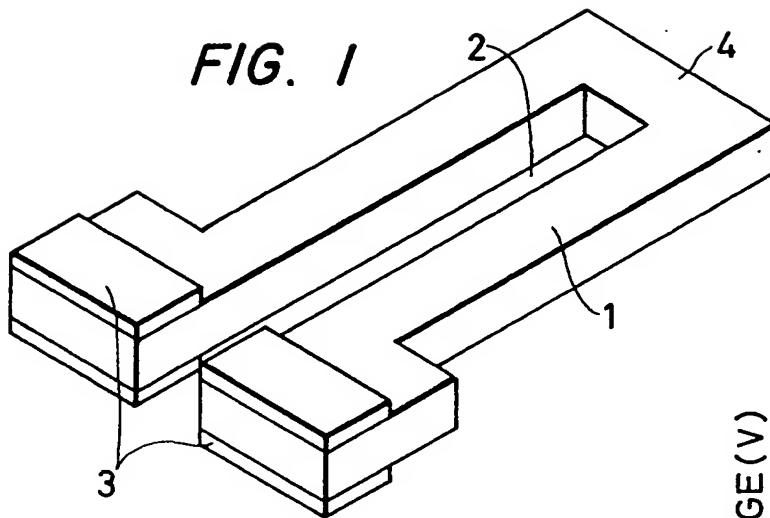


FIG. 2

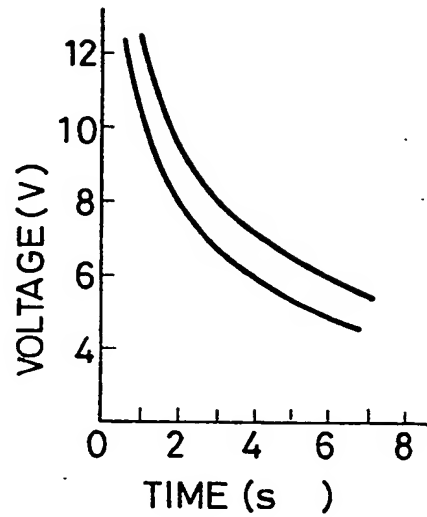


FIG. 3

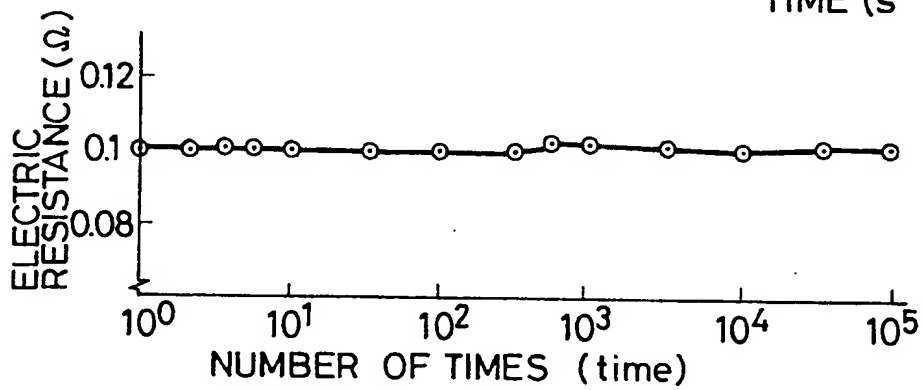


FIG. 4

